BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 09061

SUBJECT: AAP Terminal Requirements Using Intelsat IV for Communications Relay - Case 900/620

DATE: September 24, 1969

FROM: R. K. Chen

MEMORANDUM FOR FILE

I. Introduction

The use of Intelsat satellites for the relay of voice and data communications between manned space vehicles and the mission control center (MCC) was discussed in References 1 and 2. In these references, an idealized linear characteristic was assumed for the Intelsat satellite repeaters, which greatly simplified the analysis of the complete relay communication system. The simplified linear repeater model was adequate for the initial evaluation and the determination of the feasibility and practicability of using Intelsat satellites as data relay satellites.

It has been proposed recently that Intelsat IV satellites be used for data relay during the AAP missions. For the proper sizing of the relay communications system and the design of a terminal for the AAP spacecraft, the exact characteristics of the Intelsat IV repeater, which is non-linear, should be used. These characteristics have been provided by the Communication Satellite Corporation (Comsat).

This memorandum uses the latest information available on Intelsat IV for the purpose of sizing the AAP spacecraft terminal and also outlines the procedures for making the link calculations. The Intelsat IV characteristics are summarized in Section II, and a set of assumed communications requirements are given in Section III. The relay link equations and a summary of AAP terminal requirements are provided in Section IV based on the mathematical model and computational procedures established in Appendix A.

II. Intelsat IV Characteristics

The general characteristics of Intelsat IV satellite were supplied by Comsat and are shown in Tables I and II, and Figure 1. A salient feature of the Intelsat IV repeaters is their adjustable gain. For instance, the global-global repeaters* have four gain steps, 3 dB in each step, which can be changed by command from the ground control center. This feature allows the maintenance of repeater gain throughout the satellite life time and also permits control of thermal and intermodulation noises generated by the satellite repeaters.

For the voice and data relay application for the AAP missions, Comsat has suggested that NASA consider leasing one complete global-global repeater per satellite. This suggestion has several attractive features because it:

1. simplifies operational procedures,

2. minimizes interferences from other users,

3. provides flexibility as well as future growth in information transfer, and

4. permits operating the repeater at its maximum gain setting.

Subsequent analysis herein is based on the assumption of using a dedicated global-global Intelsat IV repeater for the exclusive use of AAP missions.

A critical parameter of the Intelsat IV repeater is its signal transfer characteristic which is shown in Figure 2. It is seen that the repeater does not have a constant gain** linear amplifier, which was assumed in References 1 and 2. Instead, the repeater is a variable gain amplifier with its absolute gain value depending on the input power level. The gain of the amplifier is approximately 7.5 dB less than the linear region when operating at saturated output level.

Figure 3 is the assumed antenna pattern for the Intelsat IV global antenna. For the AAP application, communications relay operation could occur beyond the $\pm$ 8.5° beamwidth of the Intelsat IV global antenna where the satellite G/T is specified. From Figure 3, it is seen that an additional 1 dB degradation can be expected when the AAP spacecraft is located at 90° central angle from the sub-satellite point of the Intelsat IV satellite.

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*The global-global repeaters are those connected to the global coverage antennas at both input and output terminals; this contrasts with the global-spot repeaters which have their output terminal connected to the spot beam antennas (see Fig.1).

**Power gain = $\frac{P_{out}}{P_{in}}$

III. Communication Requirements

The exact communications requirements for the relay links have not been determined. For the purpose of sizing up the system, the following are assumed:

Up-link	voice, 1 kbps up-data
Down-link	voice, telemetry - 72 kbps or 51.2 kbps

The performance requirements of these communications functions are given in Table III. C/N_0, carrier-to-noise spectral density ratio, is chosen as the performance parameter; it is related to the predetection signal-to-noise ratio by:

$$C/N_0 = S/N \times BW \qquad (1)$$

where BW is the predetection RF bandwidth or bit-rate bandwidth. The advantage of C/N_0 is that it is a normalized (with respect to bandwidth) parameter. By comparing the C/N_0's, one can tell immediately the relative carrier power required for different communications functions. For instance, an FM voice link with a 10 dB signal-to-noise ratio required in the predetection bandwidth (C/N_0 = 52 dB-Hz) requires 2 dB more carrier power than the up-data link which requires 10.0 dB signal-to-noise ratio in its predetection bandwidth (C/N_0 = 50.0 dB-Hz).

IV. Performance Calculations

The relay link equations are derived in Appendix A based on a simplified but valid approach for the AAP application. Two sets of up and down link equations are obtained, one set assumes that the AAP terminal is equipped with a 5.5 ft. diameter antenna and the other set assumes an 11 ft. diameter antenna. The link equations are:

For 5.5 ft. antenna

Up-Link

$$C/N_0 = (EIRP)_{GND} - 28.5 \quad \text{dB-Hz} \qquad (2)$$

$$= (EIRP)_{IS} + 34.6 \quad \text{dB-Hz} \qquad (3)$$

Down-Link

$$C/N_0 = (EIRP)_{SC} + 5.1 \quad \text{dB-Hz} \qquad (4)$$

For 11 ft. antenna

Up-Link

$$C/N_0 = (EIRP)_{GND} - 21.2 \quad \text{dB-Hz} \qquad (5)$$

$$= (EIRP)_{IS} + 41.1 \quad \text{dB-Hz} \qquad (6)$$

Down-Link

$$C/N_0 = (EIRP)_{SC} + 5.7 \quad \text{dB-Hz} \qquad (7)$$

Where: EIRP = equivalent isotropic radiated power of the transmitting station. This parameter includes the transmitting antenna gain, transmitter power, and line losses.

SC = AAP spacecraft

GND = Intelsat ground station

IS = Intelsat IV satellite repeater

The non-linear behavior of the Intelsat IV repeater becomes evident when comparisons are made between equations (2) and (5), and (4) and (7). In the up-link case, equations (2) and (5), a 7.3 dB increase in EIRP from the ground station is needed to compensate the 6 dB difference in a two-to-one change of the antenna size at the AAP terminal. The 1.3 dB difference in the link performance required is directly related to the difference in the repeater gain at the two different operating points. In the down-link case, equations (4) and (7), instead of the same 1.3 dB difference in performance as one may expect, only a 0.6 dB difference resulted. The apparent discrepancy exists because the change in repeater gain also changes the amount of effective noise temperature at the ground station contributed by the satellite repeater. As shown in Table A-IV of Appendix A, the noise temperature contributed by the satellite is 49°K for an 11 ft. diameter antenna on the AAP spacecraft but reduced to 36°K for a 5.5 ft. diameter antenna. On the other hand, the up-link is not effected by the change in satellite noise temperature as it contributes only a negligible amount, 1°K, to the AAP receiving terminal.

Typical parameters for the AAP terminal are given in Table IV. More specifically, Table IV indicates the transmitter power needed for the AAP terminal for selected voice and telemetry transmissions.

For those who are interested in either using a different size antenna on the AAP terminal or desiring a higher capacity down-link, Figure 4 is provided as an estimate. The C/N_0 requirement for PSK data at 10^{-4} BER is assumed to be 11.4dB-Hz and a 3dB line loss is assumed for the manned spacecraft transmitting terminal. If more accuracy is desired, a careful reading of Appendix A is recommended.

2034-RKC-mbr

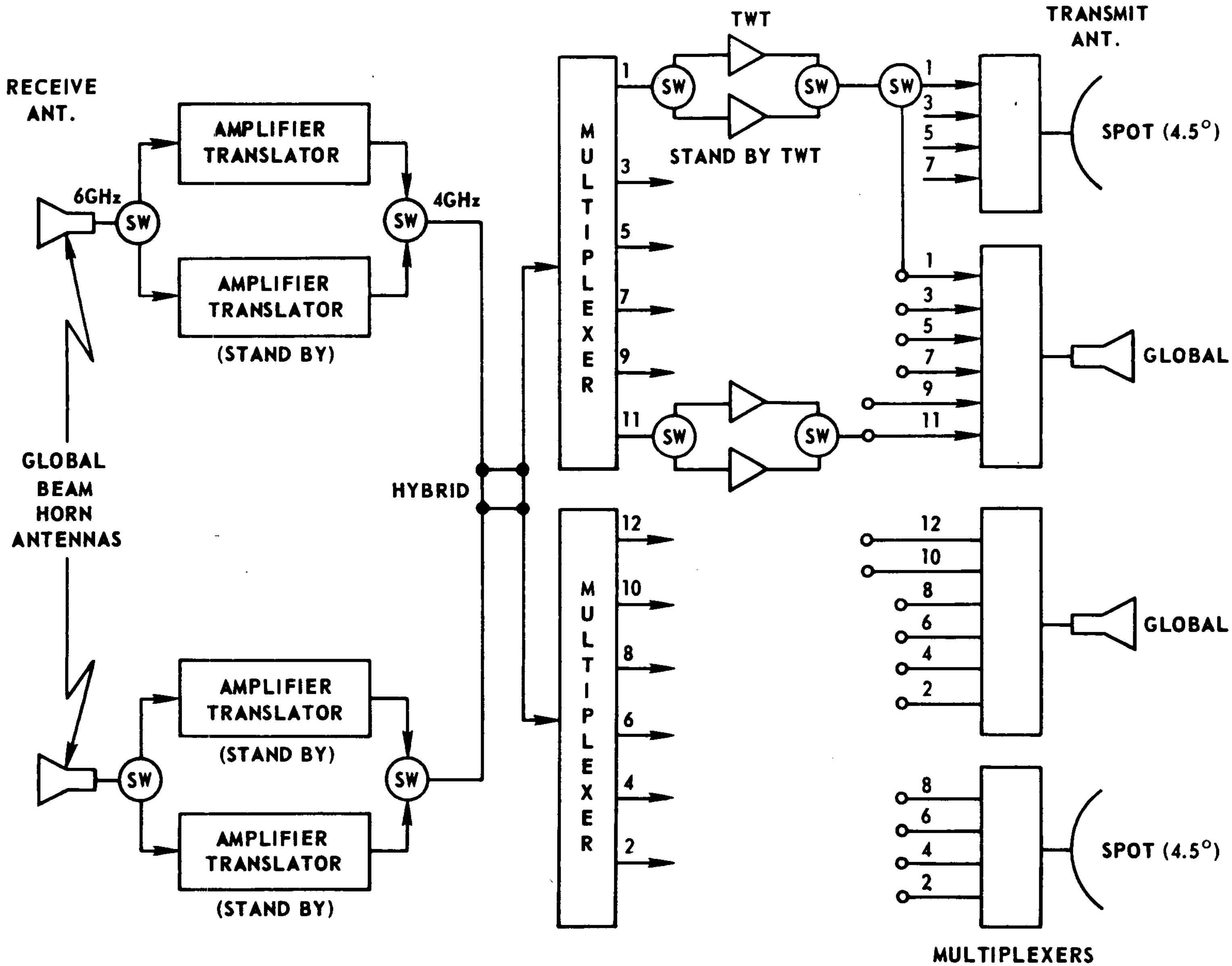
R. K. Chen

Attachments
Figures 1-4
Tables I-IV
Appendix A

REFERENCES

1. Chen, R. K., "The Use of Intelsat Sattelites for Direct Voice Communications With Manned Space Vehicles", Bellcomm, Inc. TM-68-2034-15, September 30, 1968.

2. Chen, R. K., "The Use of Intelsat Satellites for Direct Voice and Data Communications with Manned Space Vehicles", Bellcomm, Inc. TM-69-2034-2, March 31, 1969.



INTELSAT IV—COMMUNICATIONS SUBSYSTEM

Figure 1

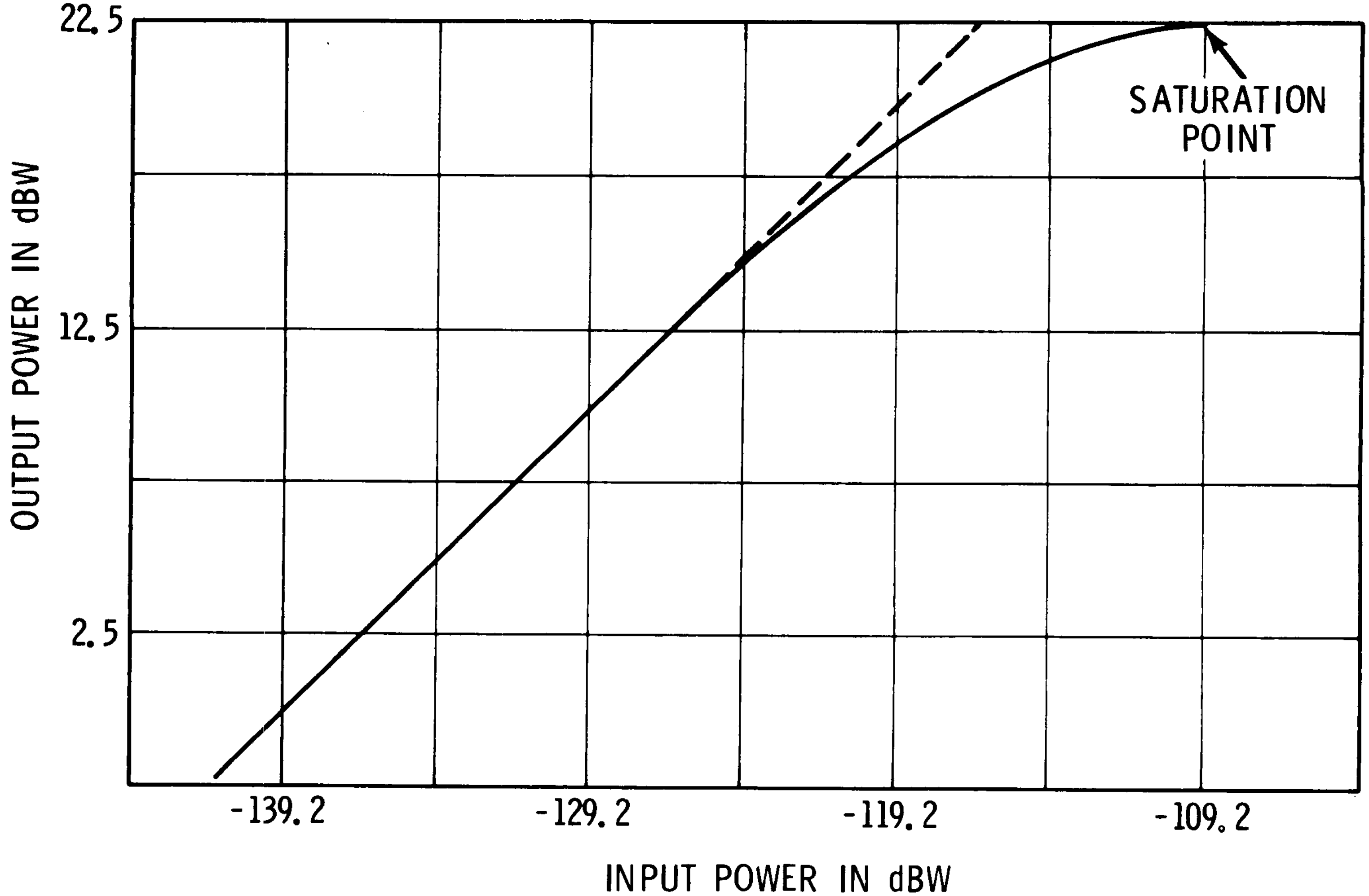


FIGURE 2 - INTELSAT IV- GLOBAL - GLOBAL DEDICATED TRANSPONDER TRANSFER CHARACTERISTIC

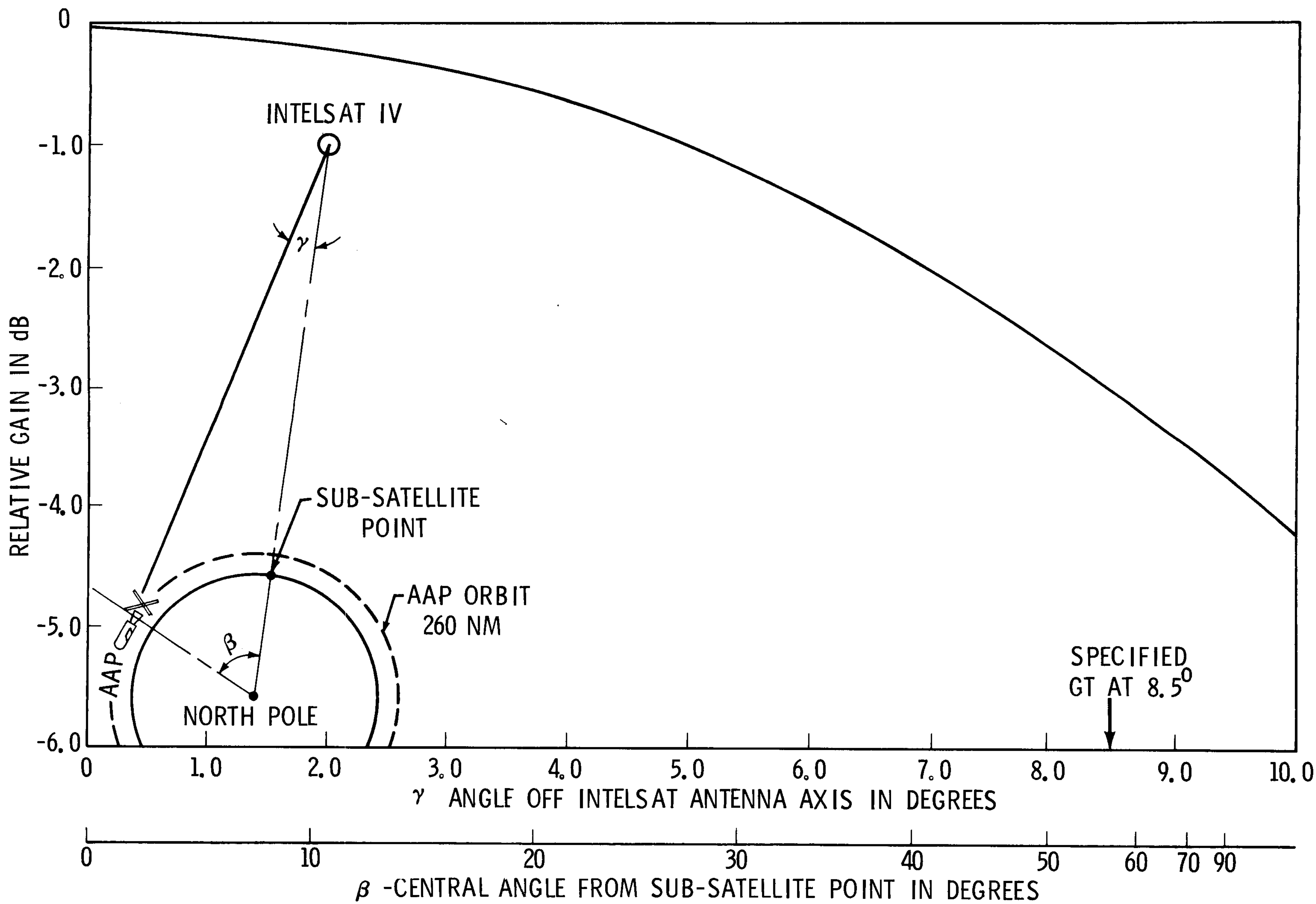


FIGURE 3 - ASSUMED INTELSAT GLOBAL ANTENNA PATTERN

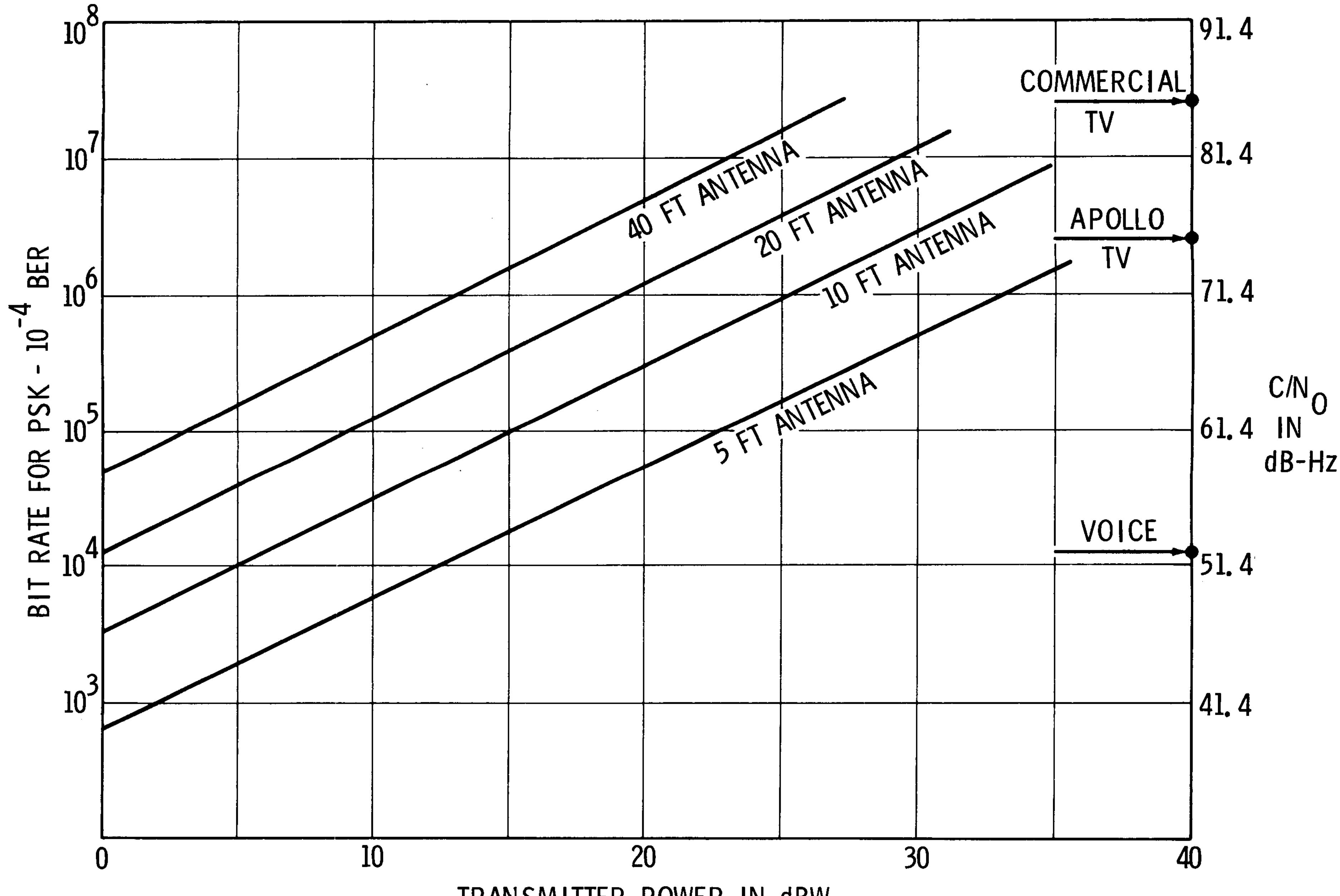


FIGURE 4 - DOWN-LINK S/C TERMINAL REQUIREMENT USING INTELSAT IV RELAY

Table 1

INTELSAT IV -- SATELLITE CHARACTERISTICS

Liftoff spacecraft weight	2760 lbs.
Useful synchronous orbit weight	1450 lbs.
Stabilization mode	spin
Attitude stabilization	± 0.25 deg.
Station keeping (E-W)	± 0.1 deg.
Orbital inclination	0.1 deg.
Power source	solar
Eclipse operation	yes
Prime solar power	565 watts

Table II
INTELSAT IV PERFORMANCE PARAMETERS

Number of transponders	Global only	4
	Spot or global	8
	Total	12
Frequency bands	Transmit	3.7 - 4.2 GHz
	Receive	5.925 - 6.425 GHz
Half power beamwidth	Global	17 deg.
	Spot	4.5 deg.
Number of spot beams		2
Beam pointing accuracy		± 0.35 deg.
Polarization	Global	Circular
	Spot	Circular
Receive G/T at beam edge		-17.6 dB/°K
Usable bandwidth per transponder		36 MHz
TWT RF power per transponder		6.3 watts
e.i.r.p. per transponder (beam edge)	Global	22.5 dBW
	Spot	33.7 dBW
Transponder gain (levels required to drive output TWT to saturation) (1).		
	Global beam, multiple carriers	-66.7 dBW/m^2
	Global beam, single carrier	-73.7 dBW/m^2
	Spot beam, multiple carriers	-57.7 dBW/m^2
	Spot beam, single carrier	-64.7 dBW/m^2
Reliability (probability of survival for 7 years operation in orbit).		
	All of 12 channels	0.33
	11 of 12 channels	0.68
	10 of 12 channels	0.87

(1) These are typical operating levels. Alternate gain settings are available and can be selected by ground command.

TABLE III

AAP COMMUNICATION PERFORMANCE REQUIREMENTS-ASSUMED

Function	Baseband Performance	Modulation	S/N Req. Pre-detection	RF Bandwidth	C/No Req.
Voice (up and down links)	T/N=20 dB (Tone to noise ratio)	FM	10 dB	15.5 kHz	52 dB-Hz
Up-data (up-Link) (1.0 kbps)	10^{-6} BER	PSK/FM	10.0 dB	10 kHz	50 dB-Hz
Telemetry (down-Link)					
-51.2 kbps	10^{-4} BER	PSK	11.4 dB*	Bit-Rate Bandwidth	58.5 dB-Hz
-72 kbps	"	"	"	"	59.9 dB-Hz

*3 dB margin included

TABLE IV

TYPICAL PARAMETERS FOR AAP TERMINAL

FUNCTIONS	5.5 FT. S/C ANTENNA		11 FT. S/C ANTENNA	
	$(EIRP)_{SC}$ (dBW)	TRANSMITTER POWER (WATT)	$(EIRP)_{SC}$ (dBW)	TRANSMITTER POWER (WATT)
Voice	46.9	16.2	46.3	3.5
TLM				
•51.2 kbps	53.4	72.5	51.8	16
•72 kbps	54.8	100	54.2	22

Assume: 3dB Transmitting Line Loss
6dB Noise Figure Tunnel Diode Amplifier Mounted Near Antenna Feed

APPENDIX A

PERFORMANCE CALCULATION FOR INTELSAT-IV RELAY

General

A model of using Intelsat IV satellite for communications relay is shown in Figure A-1, the symbols used in this appendix are identified in Table A-I. Since the Intelsat IV repeater is a frequency translation amplifier and the links between the AAP spacecraft and the ground are independent of each other, the model can be expressed mathematically as:

$$C/N_0 = \frac{EIRP \times L_6 \times L_4 \times G_{IS} \times G_R}{K\ (T_R + T_{IS} \times A_{IS} \times L_4 \times G_R)} \qquad \text{(A-1)}$$

$$= \frac{EIRP \times L_6 \times L_4 \times G_{IS} \times G_R}{K\ (T_R + T_{IS}')} \qquad \text{(A-2)}$$

The physical meaning of equation (A-2) is clear; the carrier power (C) is the power radiated by the transmitting station (EIRP) modified by: (1) the losses through the transmission pather (L_6, L_4), (2) the gain of the Intelsat IV repeater (G_{IS}), and (3) the gain of the antenna at the receiving station (G_R). The noise power spectral density (N_0) is the sum of two contributing noise temperatures, T_R and T_{IS}'. T_R is the system noise temperature of the receiving station and T_{IS}' is the noise temperature at the receiving station contributed by the noise (T_{IS}) originated at the Intelsat repeater.

Effects of Non-Linear Transfer Characteristic of Intelsat IV Repeater

As mentioned before, the gain of the Intelsat IV repeater is a variable; it depends on:

1. the gain step setting determined by the ground control, and

2. the <u>total</u> input signal power.

APPENDIX A

The gain has been assumed to be at the maximum setting with a dedicated repeater, but the gain and input power dependency needs analysing.

In functional form:

$$G_{IS} = a \times A_{IS} = f\left(\sum_{1}^{n} P_{input}\right)$$

$$= F\left(\sum_{1}^{n} EIRP\right) \qquad (A-3)$$

where a is a constant and is the total gain between the antenna input and the pre-amlifier of the Intelsat IV repeater. The summation is necessary since a minimum of two carriers will be needed for two-way communications. If the voice and data are transmitted on separate carriers, four carriers will be involved (n = 4). Combining equations (A-2) and (A-3):

$$(C/N_0)_k = \frac{L_6\ L_4\ (EIRP)_k \times F\left(\sum_{1}^{n} EIRP\right)\ G_R}{K\ T_R + \left[\dfrac{K\ T_{IS}\ L_4\ \ G_R \times F\left(\sum_{1}^{n} EIRP\right)}{a}\right]} \qquad (A-4)$$

$$k = 1, 2, 3, \text{------} n.$$

From equation (A-4), it is seen that, in order to solve for $(EIRP)_k$ with $(C/N_0)_k$ specified, a set of n simultaneous equations needs to be solved, n being the number of carriers going through the repeater. A further complication is the functional relation describing the transfer characteristic expressed by equation (A-3) and shown in Figure A-2. By bounding the repeater operation to below saturation, the transfer characteristic can be fitted approximately by a polynomial of the m^{th} order, the value of m depending on the desired accuracy of the fit:

$$P_{out} = b_0 + b_1 P_{in} + b_2 P_{in}^2 + \text{---------} + b_m P_{in}^m \qquad (A-5)$$

The gain of the repeater is the slope of the transfer characteristic:

$$G_{IS} = a\ A_{IS} = \frac{d\ P_{out}}{d\ P_{in}} = b_1 + 2b_2 P_{in} + \text{---} + mb_m P_{in}^{m-1} \qquad (A-6)$$

When equation (A-6) is substituted into equation (A-4), the problem is solving a set of n simultaneous equations of the m^{th} order.

Simplified Approach

Under certain conditions, the problem can be simplified by using the approximation that the operating point of the repeater, and therefore its gain, is dictated by the up-link requirement. Using this approximation, the gain of the repeater can be determined graphically using Figure A-2 by making the up-link calculation first, which effectively obviates the need of solving higher order equations simultaneously.

The EIRP required from the satellite repeater for a given communication function depends on the figure of merit of the receiving terminal, which is the parameter G/T. It is a measure of the net gain of the receiving antenna and the effective receiving system noise temperature. A standard Intelsat ground station is specified to have a minimum $(G/T)_S$ of 40.7 dB/°K. Physically, the standard terminal could have an 85 ft. diameter antenna with a maser receiver, a 97 ft. diameter antenna with a cooled parametric amplifier, or other combinations. It is apparent that any practicable receiving terminal for the AAP spacecraft will not approach the performance of the standard Intelsat ground station:

$$(G/T)_{AAP} \ll (G/T)_S = 40.7 \text{ dB/°K} \qquad \text{(A-7)}$$

or the EIRP required from the Intelsat IV repeater for the up-link is much greater than that needed for the down-link for the same communications function:

$$(EIRP)_{IV\text{-up-link}} \gg (EIRP)_{IV\text{-down-link}}$$

and the ratio of the EIRP required is related to the G/T's as:

$$\frac{(EIRP)_{IV\text{-up-link}}}{(EIRP)_{IV\text{-down-link}}} = \frac{(G/T)_S}{(G/T)_{AAP}} \gg 1 \qquad \text{(A-8)}$$

APPENDIX A

For general cases where the communication functions of the up and down links are different, the relative EIRP from the repeater for the up and down links is:

$$\frac{(EIRP)_{IV\text{-up-link}}}{(EIRP)_{IV\text{-down-link}}} = \frac{(G/T)_S}{(G/T)_{AAP}} \times \frac{\Sigma (C/N_0)_{up\text{-link}}}{\Sigma (C/N_0)_{down\text{-link}}} \qquad \text{(A-9)}$$

If we assume that the up-link requirements determine the satellite gain when the EIRP needed for the up-link is ten times greater or more than that needed for the down-link, the following condition must be satisfied:

$$\frac{(G/T)_S}{(G/T)_{AAP}} \times \frac{\Sigma (C/N_0)_{up\text{-link}}}{\Sigma (C/N_0)_{down\text{-link}}} \geq 10 \qquad \text{(A-10)}$$

The condition of (A-10) is easily satisfied for the AAP application. If we assume that the AAP spacecraft can be outfitted with an antenna with a maximum diameter of 20 ft., which has a gain (G) of 59 dB, and a receiving system using a tunnel diode amplifier with an effective system noise temperature (T) of 1160°K, then $(G/T)_{AAP}$ is 18.4 db/°K. The ratio of the G/T's is:

$$\frac{(G/T)_S}{(G/T)_{AAP}} = 22.3 \text{ dB or a factor of } 170.$$

Therefore, the down-link performance requirement must be 17 or more times greater than the up-link performance requirement before the condition of (A-10) is violated. From Table III, the combined performance requirement for the up-link is 54.1 dB-Hz; this means that the down-link performance requirement can be as high as 66.4 dB-Hz, which is equivalent to a voice link plus a 200 kbps telemetry link. Such a high telemetry data rate is not planned for the AAP application at this time.

T_{IS}' - Noise Contributed by the Satellite Repeater

It is instructive to examine the effect of noise contributed by the satellite repeater, T_{IS}'. From equations (A-1) and (A-2):

$$T_{IS}' = T_{IS} \times A_{IS} \times L_4 \times G_R \qquad \text{(A-11)}$$

APPENDIX A

Assuming the maximum gain of the satellite repeater, A_{IS} = 126 dB, and using the values of other parameters provided in Table A-I,

T_{IS}' = 16.9 dB-°K = 50°K at the standard Intelsat ground station, and:

T_{IS}' = 0 dB-°K at the AAP terminal with 11 ft. diameter antenna.

It is seen that T_{IS}' contributes significantly to the effective temperature at the Intelsat ground station, which has a system noise temperature of 50°K. It is also seen that T_{IS}' could be neglected at the AAP terminal, which could have a system noise temperature of 1160°K.

Link Equations

Using the simplified approach, the operating point of the satellite repeater is found by making half of the up-link calculation, the portion between the Intelsat IV and the AAP spacecraft:

$$(\Sigma C/N_0)_{\text{up link}} = \frac{(EIRP)_{IS} \times L_4 \times (G/T)_{AAP}}{K} = 54.1 \text{ dB-Hz} \quad \text{(A-12)}$$

Substituting values for the parameters:

$(EIRP)_{IS}$ = 13.0 dBW for 11 ft. diameter antenna on AAP, and

$(EIRP)_{IS}$ = 19.0 dBW for 5.5 ft. diameter antenna on AAP.

Using Figure A-2, the gain of the repeater at these operating points are:

G_{IS} = 139 dB for 11 ft. diameter antenna on AAP, and

G_{IS} = 137.7 dB for 5.5 ft. diameter antenna on AAP.

With the gain value of the satellite repeater found, equation (A-2) can be used to derive the link equations. Figures A-3 and A-4 show the results for the up and down link.

Attachments
Figures A-1 - 4
Table A-I

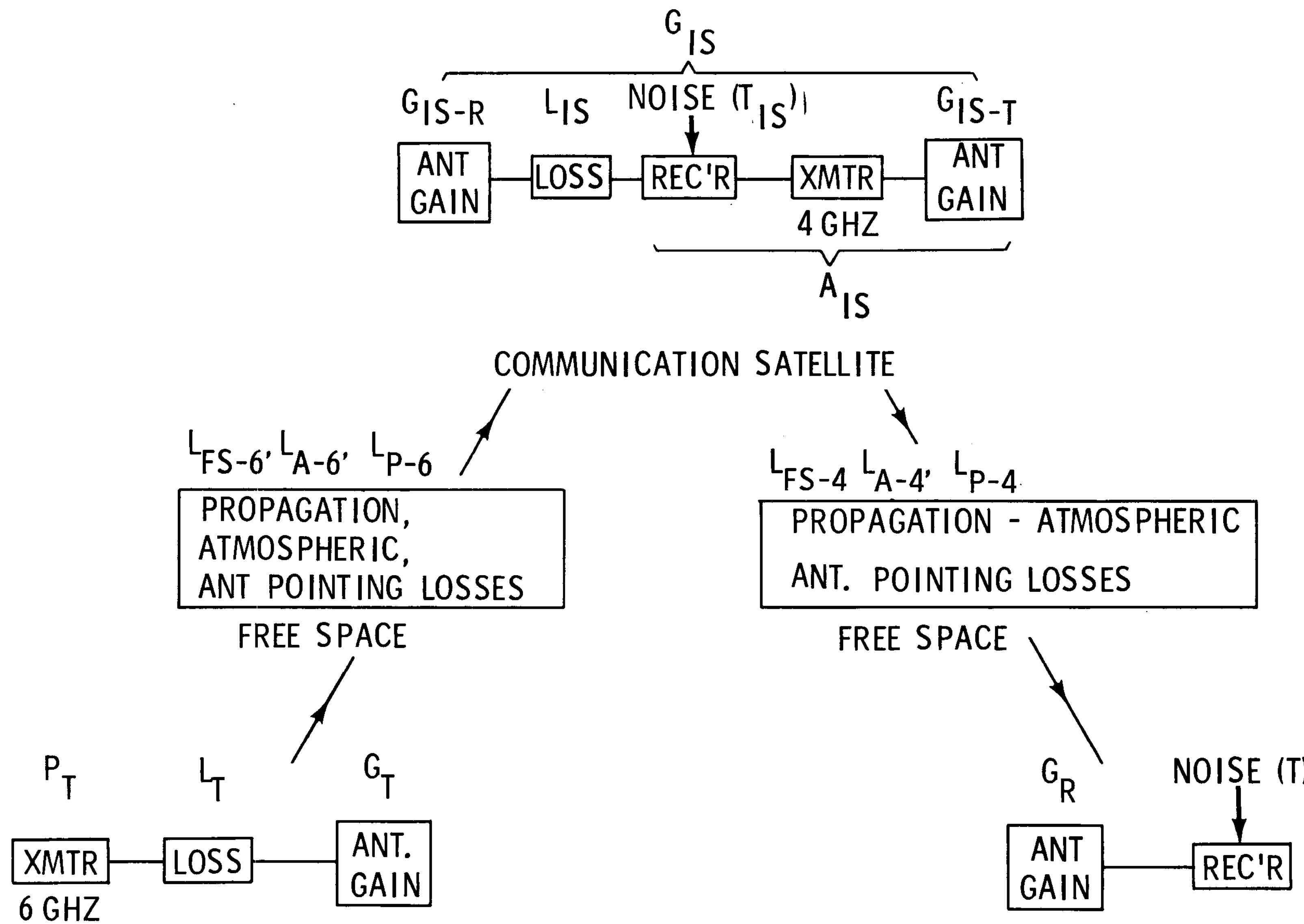


FIGURE A-1 - MODEL OF INTELSAT COMMUNICATIONS SATELLITE FOR DATA RELAY

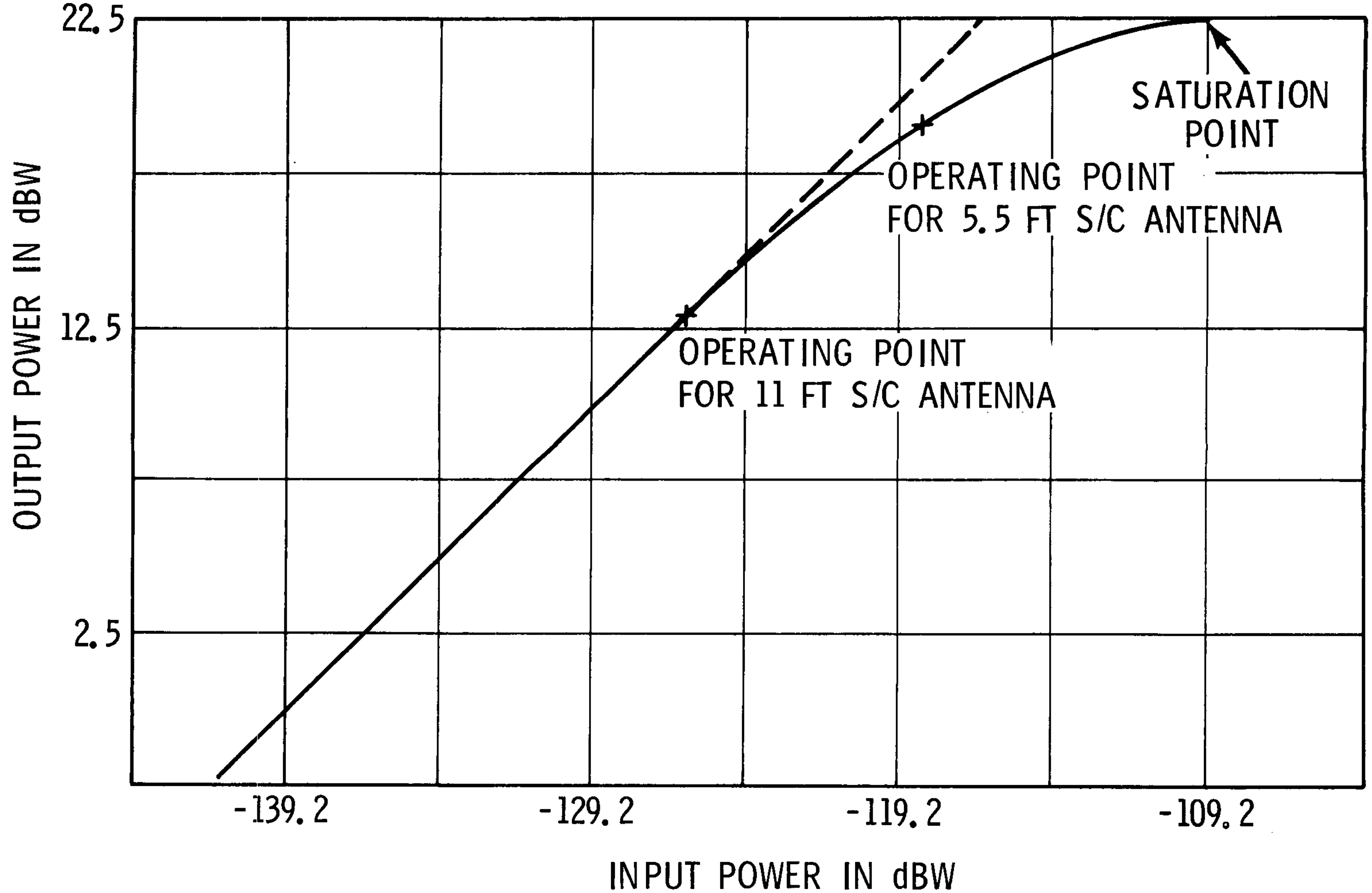
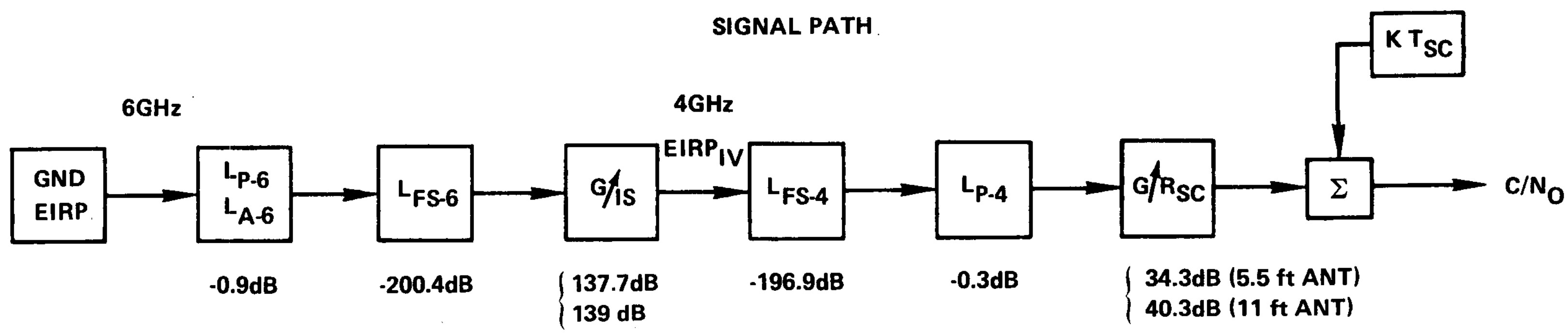


FIGURE A-2 - INTELSAT IV - GLOBAL-GLOBAL DEDICATED TRANSPONDER TRANSFER CHARACTERISTIC



$C = (EIRP_{GND} - 226.5)$ dBW for 5.5 ft Dia. S/C ANTENNA

$C = (EIRP_{GND} - 219.2)$ dBW for 11.0 ft Dia. S/C ANTENNA

$T_{SC} = 1160^{o}K$

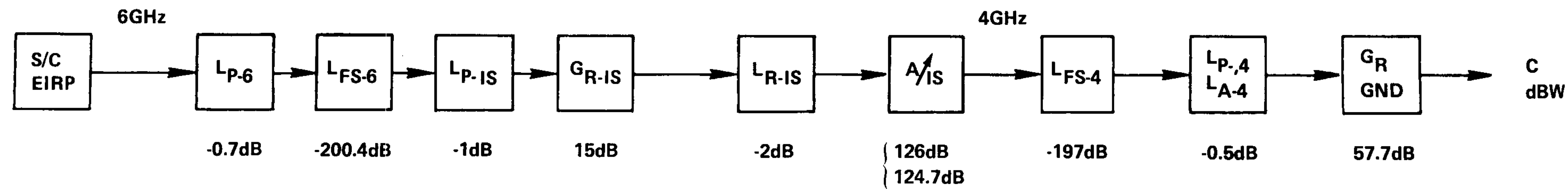
$N_{O_{SC}} = -198$ dBW/ Hz

$$\left.\begin{aligned} C/N_O &= (EIRP_{GND} - 28.5) \text{ dB-Hz} \\ &= (EIRP_{IV} + 34.6) \text{ dB-Hz} \end{aligned}\right\} \text{ for 5.5 ft. Dia. S/C ANTENNA}$$

$$\left.\begin{aligned} C/N_O &= (EIRP_{GND} - 21.2) \text{ dB-Hz} \\ &= (EIRP_{IV} + 41.1) \text{ dB-Hz} \end{aligned}\right\} \text{ for 11 ft Dia. S/C ANTENNA}$$

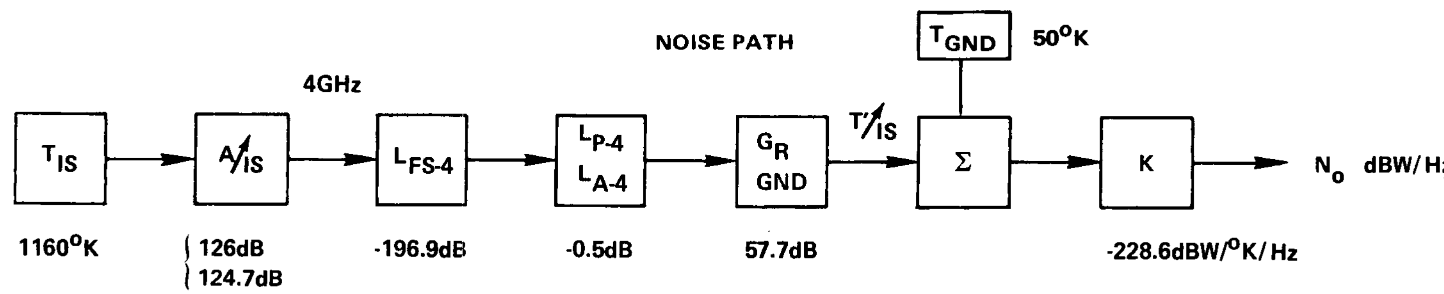
FIGURE A-3. UP-LINK CALCULATION – USING INTELSAT-IV GLOBAL-GLOBAL DEDICATED TRANSPONDER

SIGNAL PATH



$C = (EIRP_{SC} - 204.2)$ dBW for 5.5 ft Dia. S/C ANTENNA

$C = (EIRP_{SC} - 202.9)$ dBW for 11 ft Dia. S/C ANTENNA



$T_{IS} = 1160^oK$ $\qquad$ $T_{GND} = 50^oK$

$T_{IS}' = 15.6$ dB-^oK = 36^oK for 5.5 ft. Dia. S/C ANTENNA

$T_{IS}' = 16.9$ dB-^oK = 49^oK for 11 ft. Dia. S/C ANTENNA

$N_o = -209.3$ dBW/Hz for 5.5 ft. Dia. S/C ANTENNA

$N_o = -208.6$ dBW/Hz for 11 ft. Dia. S/C ANTENNA

$C/N_o = (EIRP_{SC} + 5.1)$ dB-Hz for 5.5 ft. Dia. S/C ANTENNA

$C/N_o = (EIRP_{SC} + 5.7)$ dB-Hz for 11 ft. Dia. S/C ANTENNA

FIGURE A-4. DOWN-LINK CALCULATION – USING INTELSAT-IV GLOBAL-GLOBAL DEDICATED TRANSPONDER

TABLE A-I

LIST OF ASSUMED PARAMETERS

L_{FS-6} - Space Loss at 6GHz, -200.4dB

L_{FS}-4 - Space Loss at 4GHz, -196.9dB

L_P-6 - Antenna Pointing Loss at 6GHz
For Earth Station, -0.1dB
For Manned Spacecraft, -0.7dB (1/4 beamwidth)
For Intelsat-IV, -1dB for the link to and from Manned Spacecraft

L_P-4 - Antenna Pointing Loss at 4GHz
For Earth Station, -0.1dB
For Manned Spacecraft, -0.3dB

L_A - Atmospheric Loss, -0.4dB at 4GHz
-0.8dB at 6GHz

G_R - Receive Antenna Gain
For Earth Station, 57.7dB (85 ft. Dia.)
For Manned Spacecraft, 40.3dB (11 ft. Dia.)
34.3dB (5.5 ft. Dia.)

T - Receiving System Noise Temperature
For Earth Station, 50° K
For Manned Spacecraft, 1160° K

L_T - Transmitting Line Loss
For Manned Spacecraft, -3dB

G_{IS} - Intelsat IV Transponder Gain (Antenna to Antenna)
Variable, Assumed: 139.0dB for 11 ft. s/c Antenna
137.7dB for 5.5 ft. s/c Antenna
Using Global - Global Dedicated Transponder for AAP Operations

G_{IS-R} - Intelsat IV Receive Antenna Gain
14dB at $\pm 8.5°$ off Antenna Axis

L_{IS} - Intelsat IV Line Loss, -2dB

T_{IS} - Intelsat IV Receiving System Noise Temperature, 1160° K

A_{IS} - Intelsat IV Amplifier Gain

$$= G_{IS} - G_{IS-R} - L_{IS}$$

G_T - Transmitting Antenna Gain,
For Manned Spacecraft, 43.8dB for 11 ft. s/c Antenna
37.8dB for 5.5 ft. s/c Antenna

EIRP - Equivalent Isotropic Radiated Power of the transmitting station. This parameter includes antenna gain (G_T), transmitter power, and line losses (L_T).

L_6 = All losses associated with the 6GHz transmission path from transmitting station to Intelsat IV. This parameter includes free space loss, atmospheric attenuation, and antenna pointing loss.

L_4 = Same as L_6 except it is associated with the 4GHz transmission path from Intelsat IV to receiving station.

K = Boltzmann's Constant

Manned Spacecraft Orbit - 260 n.m. Circular

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

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FROM: R. K. Chen

ABSTRACT

Intelsat IV satellites have been proposed as a data relay satellite system for the AAP missions. Using the latest available information from Comsat Corp. on the Intelsat IV characteristics, a set of typical AAP terminal parameter values is calculated. The terminal sized would have a tunnel diode amplifier mounted near the antenna feed, and the antenna is assumed to be either 5.5 ft. or 11 ft. in diameter. The up-link receives voice and 1.0 kbps of up-data, and the down-link transmits voice and up to 72 kbps of telemetry. The transmitter power needed to transmit voice and 72 kbps of data when using an 11 foot diameter antenna is 25.5 watts. A 5.5 ft. antenna terminal would be capable of transmitting voice alone with 16.2 watts of transmitter power; 100 watts of additional power would be needed to send 72 kbps of data.